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Pressure Transducer for Remote Data Acquisition

(U.S.) Robert S. Kerr Environmental Research Lab.
Ada, OK

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Pressure Transducer for Remote Data Acquisition

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ABSTRACT

AN inexpensive transducer which gives a frequency output as a function of pressure input has been developed and tested under field conditions. The linearity of the transducer is three percent over the tested range—20,000-80,000 Pa (0.2 to - 0.8 bars) of pressure. The transducer is linearly temperature-dependent due to the dielectric properties of the materials used in assembly.

INTRODUCTION

Numerous tensiometers are used around the world for irrigation management, as well as research on soil water relations. Many man-years of effort are required to make and record the observations from these measurements. Primary drawbacks to automated data acquisition include—the cost of strain gauge type of pressure transducers, and problems in response time when a single transducer is used with fluid switching devices having a small amount of air in the system. The purpose of this study was to develop an inexpensive transducer from readily available material which could be used under field conditions.

The approach provides a method of assessing the level of mercury in a standard mercury manometer. Measurements can be calibrated to within approximately 100 Pa (1 mbar); thus, it is compatible with most water management and research needs.

METHODS AND MATERIALS

The basic principal of operation of the pressure transducer is the same as a concentric capacitor. The capacitance of the transducer would follow the equation

$$C = \frac{24.1\ KL}{\log_{10} \frac{D}{d}} \quad \ldots\ldots\ldots\

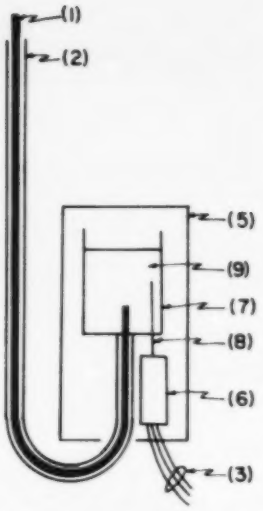

FIG. 2 Alternate configuration of pressure transducer where positive, as well as negative, pressures can be monitored. Number designations same as Fig. 1.

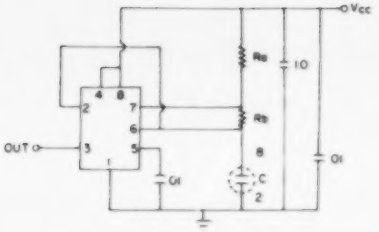

FIG. 3 Schematic diagram of multivibrator circuit numbers (2) and (8) reference parts in Figs. 1 and 2. The integrated circuit was an LM555C; capacitors are in microfarads. V_{cc} is the supply voltage 5-15 V D.C.

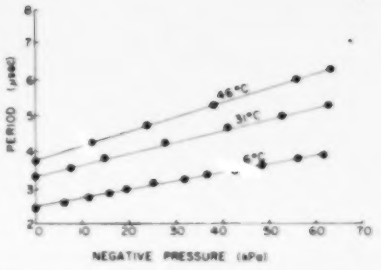

FIG. 4 Response curves at three temperatures.

stability was used to convert the capacitance to frequency (Fig. 3). The time period of this circuit can be given by the equation

$$T = 0.693\ (Ra + 2Rb)\ C \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ [2]$$

where

T = the time period in seconds
Ra = the resistance in ohms of resistor Ra
Rb = the resistance in ohms of resistor Rb
C = the capacitance in farads of the transducer plus coupling and stray capacitance due to parts location.

Since the capacitance is composed of two parts, pressure related components and stray components due to parts location, equation [2] can be written as

$$T = 0.693\ (Ra + 2Rb)\ C_p + 0.693\ (Ra + 2Rb)\ C_s \quad \ldots\ldots\ [3]$$

where

C_p = capacitance due to height of mercury in the manometer L
C_s = stray capacitance.

This simplifies to

$$T = mL + b \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ [4]$$

where

m = slope of calibration curve
L = pressure applied to the manometer
b = constant offset due to parts location and geometry of the manometer.

RESULTS AND DISCUSSION

Typical calibration curves are shown in Fig. 4. Minor fluctuations in true linear calibration are believed to be caused by the differences in the wall thickness of the nylon tubing. From the calibration curve, it is possible to calculate the dielectric constant of the nylon using equation [1]. At 31 °C the dielectric constant was 4.6, which is within the reported range of 3.4 to 22.4 found in the literature (Tremaine, 1973).

Dielectric properties of most materials change with temperature. To determine the temperature coeffieicnt of nylon's dielectric constant, it was necessary to evaluate the thermal sensitivity of the circuitry excluding the manometer. Using a fixed capacitor to simulate the manometer, the output frequency was monitored over a temperature range of 0 to 40 °C. No appreciable drift was observed in the frequency output. However, when the entire unit was calibrated at three different temperatures significant differences were observed. Fig. 4 shows calibration curves at 6, 31, and 46 °C. It can be seen that the temperature significantly affects the calibration of the transducer. Fig. 5 shows how the slope (m of equation [4]) and intercept (b of equation [4]) of the calibration curves change with temperature. Since these are linear relationships, it can be shown that over the observed temperature range the dielectric constant is a linear function of temperature and follows the equation

$$K = 3.05 + 0.0498t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ [5]$$

where t is the temperature in degrees C.

Thus, by measuring the ambient temperature and the time period of the measuring system, one can calculate the pressure of the manometer with reasonable accuracy ± 100 pascals (1 mbar), using the general equation

$$L = \frac{5.98 \times 10^{10}\ T\ (\log \frac{D}{d})}{(Ra + 2Rb)\ (3.05 + 0.0498t)} \quad \ldots\ldots\ldots\ldots\ [6]$$

Current modifications have substituted Teflon 9AWG wire sleeving as the dielectric material. This has removed the temperature dependence as a slight increase in cost allowing equation [4] to be applied unaffected by temperature.

Resistors Ra and Rb were selected at 47 K ohms such

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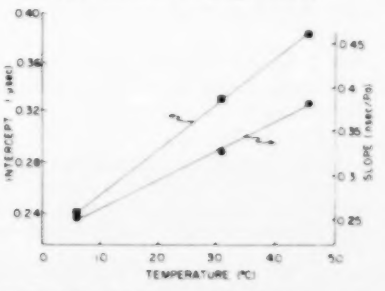

FIG. 5 Sensitivity of calibration curves to temperature.

that the range in frequency from the system would be within the audio spectrum. This was done to minimize problems of impedance loading associated with the transmission of high frequency signals. The 1 μF and 0.01 μF capacitors were installed across the power supply to minimize the effects of high switching currents on the power supply caused by the switching characteristics of LM555 integrated circuit. Without these capacitors, oscillations in the power supply produced parasitic oscillations in the transducers when more than one transducer was connected to the same power supply or long power supply leads are employed.

References

1 Tremaine, Howard M. 1973. Audio Cyclopedia. Indianapolis, IN. Howard W. Sams and Co., Inc. p. 1697.